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VOL. 22, SEC. F. MAY, 1944 NUMBER 3

EFFECTS OF CONDITIONS OF STORAGE ON THE STABILITY OF ASCORBIC ACID IN VARIOUS CARRIERS[1]

BY J. B. MARSHALL[2], J. W. HOPKINS[3], AND G. A. YOUNG[4]

Abstract

Fortified chewing gum, hard candy, jam to which ascorbic acid had been added after processing, ascorbic acid tablets, and a natural orange concentrate were stored under controlled conditions for periods up to one year. The data show that 70 to 80% of the ascorbic acid remained stable for protracted periods if the carriers were protected from moist conditions and not subject to temperatures in excess of 23.9° C. When exposed to conditions of high relative humidity and temperature the products became objectionable from the standpoint of physical appearance before the ascorbic acid losses became excessive. Fortified jams retained 75% of the added ascorbic acid after six months at 23.9° C.

Introduction

Wartime difficulties of transportation and production have curtailed the supplies of vitamin C available in Canada in the form of citrus fruits and canned juices. Other fruits and vegetables must serve as the main source of ascorbic acid, and these, under certain circumstances, may be quite inadequate (2). Supplemental sources of ascorbic acid may be provided and shipping space and tinplate saved by concentrating citrus juices to syrups or toffee-like solids, or by utilizing synthetic ascorbic acid to fortify a variety of materials.

Normally the natural concentrates would be preferred to the synthetic sources, but for service rations, to be used under a variety of conditions of climate and accessibility of supply, the stability of the ascorbic acid in the products and acceptability of the carrier to the individual consumer must be considered as well. This paper describes the results of experiments in which one natural and four fortified products were stored for periods up to one year to ascertain the effects of storage temperature and humidity on the stability of the ascorbic acid.

Losses of ascorbic acid in fortified jams during three months' storage, presumably at room temperature, have been reported to be less than 20%

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[2] *Biologist.*

[3] *Statistician.*

[4] *Laboratory Assistant.*

of the total present when 3 to 4 mg. per gram had been added (3). Ascorbic acid was added to the finished jams without affecting its stability. Fortified sweets, held in "careful storage" lost 14% of the added ascorbic acid (1).

In the present work the materials used represent a choice of carriers that would afford a considerable saving in shipping space and packaging materials. No attempt has been made to assess the properties of the materials or ingredients that might affect the stability of the ascorbic acid, nor has consideration been given to the methods of processing. It is recognized that improvements in processing technique might improve the suitability as carriers of some of the materials.

Materials

Only materials produced by commercial firms were investigated; the natural orange concentrate was an experimental product, while the gum and candy were prepared at the request of these laboratories. The jams, which were fortified in the laboratory, and ascorbic acid tablets were obtained from regular commercial stocks. Details of each of the materials follow.

Gum

The chewing gum used was of the sugar coated tablet type fortified to give a calculated level of 6.36 mg. of ascorbic acid per coated tablet. The ascorbic acid was incorporated in the centres during preparation. On receipt, specimens were found to contain 96% of the estimated amount. After two months' storage in an electric refrigerator, these samples contained 92% of the calculated level. The results for individual tablets were uniform, indicating that the method of incorporation was satisfactory both with regard to mixing and retention during processing.

Hard Candy

Hard candy drops were prepared according to a regular commercial formula except that 5% of citric acid was used in the mix. Ascorbic acid (3.5 mg per gram) was added at a late stage in the processing. Assays made on a number of tablets showed uniform incorporation of the ascorbic acid and a loss of about 22% during processing. These losses were reduced to 5% in subsequent production.

Orange Concentrate

Two lots of material, consisting of pieces of concentrate individually wrapped in double layers of heat sealed cellophane, were tested. The lot used in the first experiment was made from fresh orange juice and was more uniform and of a higher initial vitamin C content than the second lot, which was made later in the season from canned juice. The texture and physical appearance of the tablets from the second lot were more variable as well.

Ascorbic Acid Tablets

Commercially available tablets of 50 and 100 mg. potencies, manufactured by the same firm, were used.

Jams

Samples of government standard grade 2 strawberry, raspberry, peach, and plum jams were fortified at about 3.5 mg. per gram. The ascorbic acid was added to the jam in the laboratory by dusting a weighed quantity on the surface of the jam as it was being stirred in a "Mix-Master" running at low speed. The mixer was allowed to run for 20 min. in each case. Air, incorporated in the jam by this process, doubtless has affected the results, but since all samples received similar treatment this factor may be considered constant between samples.

Experimental

In the experiments with the gum, candy, orange concentrate, and tablets, sufficient material was placed in storage, under the conditions described below, to permit removal of duplicate samples at specified intervals. Initial weights and weights at the time of assay were recorded. All calculations are based on the initial weights, and the final weights were used for estimating the moisture uptake by the materials.

The first lot of orange concentrate was stored at temperatures of −1.1°, 15.6°, 23.9°, and 37.8° C. (30°, 60°, 75°, and 100° F.) each at relative humidities of 20, 50, 75, and 95%. These were obtained by using appropriate concentrations of calcium chloride. Specimens of the second lot of orange concentrate together with gum and hard candy were placed in storage at 15.6°, 23.9°, and 37.8° C. and at relative humidities of 50, 75, and 95%. In both of these experiments the individual pieces of orange concentrate were wrapped, the gum and candy, unwrapped. In addition, pieces of gum, hard candy, and orange concentrate were sealed in 7-oz. tin cans. Each individual piece was placed in a small, waxed paper envelope, open at one side. One set of tins was evacuated and filled with carbon dioxide. These were stored at 15.6°, 23.9°, and 37.8° C.

Samples were assayed for ascorbic acid content at intervals of six weeks, three months, six months, and one year in all cases and an additional sample of the first lot of orange concentrate was assayed at three weeks.

A similar plan was followed with the ascorbic acid tablets. Duplicate samples of 50 and 100 mg. units were stored at 15.6°, 23.9°, and 37.8° C., in small screw cap vials, and at 50 and 75% relative humidity. Assays were made after three weeks, six weeks, and three months of storage.

The jams were stored in completely filled, 2-oz. hermetically sealed cans at temperatures of 15.6°, 23.9°, 37.8°, and 43.3° C. (60°, 75°, 100°, and 110° F.). Single tins of each jam were withdrawn at intervals of three weeks, six weeks, three months, and six months.

The methods of extraction and determination of ascorbic acid were varied somewhat with the materials. Candy, orange concentrate, and the tablets were dissolved in 2% metaphosphoric acid and made to volume. The gum was first reduced to a fine powder by grinding individual tablets in a chilled porcelain mortar with chips of dry ice. The powder was then stirred with

2% metaphosphoric acid and the mixture filtered and made to a volume of 100 ml. by washing. Reduced ascorbic acid in these extracts was determined by titration with 2,6-dichlorophenolindophenol. The jams were extracted with the same acid and made to volume. Appropriate dilutions were made for determination using an Evelyn colorimeter. No dehydro ascorbic acid was found in any of the extracts tested, therefore this determination was not continued.

Results

The Effect of Storage on the Physical Appearance of the Material

Changes in the physical appearance of the fortified material during storage are described in the following sections. As no control or unfortified samples were stored and inspected it is not possible to assess the effect of the presence of ascorbic acid on the physical deterioration of the products. Similar changes, i.e., caramelization of the sugar and sorption of water would be expected.

Chewing Gum

Under conditions of dry storage, the gum tablets remained outwardly unchanged, but the centres were somewhat softened at 37.8° C. In the controlled humidity experiment the gum coatings remained unchanged at 50% relative humidity, but were increasingly affected as the temperatures and humidities increased. The sugar partially dissolved and became discoloured, finally leaving the darkened centres fully exposed in a brown syrup.

Hard Candy

This material was not greatly affected at 15.6° C. and 23.9° C. in dry storage in air, but became darkened and somewhat opaque at 37.8° C. The effects of evacuating the containers and filling them with carbon dioxide were evident in the scaly blistered appearance of all the samples treated in this fashion. The candy remained relatively unaffected at 15.6° C. and 50% relative humidity, but as temperatures and humidity increased, especially at the later sampling times, the pieces were more or less dissolved and the resulting syrup darkened as the temperature increased.

Natural Orange Concentrate

The shape and appearance of this material were affected to a more pronounced degree in the dry storage than those of the preceding materials. The samples from the second lot were not uniform in texture and individual pieces reacted differently. At 37.8° C. the pieces became misshapen, streaked, and darkened in colour. Those from the evacuated and carbon dioxide filled tins were frothy in appearance and contained many small vacuoles. Individual pieces that retained the original texture to a greater degree had lost less vitamin C. Although the wrappers protected pieces stored in the controlled humidity experiments to some extent, the material deteriorated much more markedly in appearance than the gum and candy. It caramelized more readily and became very dark brown in colour at 23.9° C. and 37.8° C. The wrapped capsules frequently ruptured under the pressure of the water penetrating the cellophane.

Ascorbic Acid Tablets

In storage at all of the above conditions and in the refrigerator, these tablets, originally white, tended to become faintly mottled with brown. Discoloration was more pronounced in the 100 mg. units at all three temperatures, but particularly at 75% relative humidity and 37.8° C. The tablets at this condition were a tan colour at three weeks and gave an olive green solution when dissolved. These effects were slightly more pronounced at the later samplings, the 50 mg. units becoming markedly discoloured at 75% relative humidity and 37.8° C. None of the tablets disintegrated or dissolved.

Jams

In general the colour and taste of the jams remained unchanged at 15.6° C. and 23.8° C., but deteriorated at the higher temperatures. The plum jam darkened and developed a slight off-flavour in three weeks at 37.8° C. and all of the jams showed changes at 43.3° C. These changes were accentuated at six weeks and at three months. Raspberry and plum jams showed the greater deterioration, and strawberry and peach, considerably less. After six months at 37.8° C. slight pressure developed in the cans but at 43.3° C there was considerably more. The seeds of the raspberry jam had decomposed at this temperature.

Effects of Storage on the Stability of Ascorbic Acid in the Material

Ascorbic acid assay data for the materials as received and at the commencement of storage are given in Table I, together with standard deviations, except for the jams. The results for gum and ascorbic acid tablets are expressed as mg. per tablet rather than per unit weight. Corrections for

TABLE I

ASCORBIC ACID CONTENT OF EXPERIMENTAL MATERIAL AS RECEIVED AND AT THE COMMENCEMENT OF STORAGE

Material	Ascorbic acid content		
	As received		As stored
	Mean	S.d.	
Gum, mg./tablet	6.05	0.12	5.85
Candy, mg./gm.	2.72	0.05	2.67
Orange concentrate, mg./gm.			
(1)	3.18	0.10	3.18
(2)	2.92	0.87	2.92
Ascorbic acid tablets, mg./tablet			
50 mg. unit	50.3	0.17	50.3
100 mg. unit	110.4	0.72	110.4
Jams, mg./gm.			
Strawberry	0.00		3.70
Raspberry	0.01		3.10
Plum	0.00		3.45
Peach	0.00		3.40

variations in the weights of individual tablets of the latter were made, but this was not possible for the gum because of variations in the amount of sugar coating on the fortified centres.

The effects of conditions of storage on the stability of the ascorbic acid are shown in Figs. 1 to 4. In Section *A* of Figs. 1, 2, and 3 the effects of temperature are averaged for all humidities, including dry storage in air, or the equilibrium moisture conditions resulting in the sealed cans. The screw cap vials used for the ascorbic acid tablets are treated in the same manner. Section *B* shows the effects of differences in relative humidities, averaged for all temperature conditions. Increasing temperature and relative humidity combine in all cases to destroy the ascorbic acid. The cellophane wrapper used on Lot 2 of the orange concentrate appeared to give it greater protection than was afforded Lot 1, but it is also possible that the stability of ascorbic acid in Lot 2

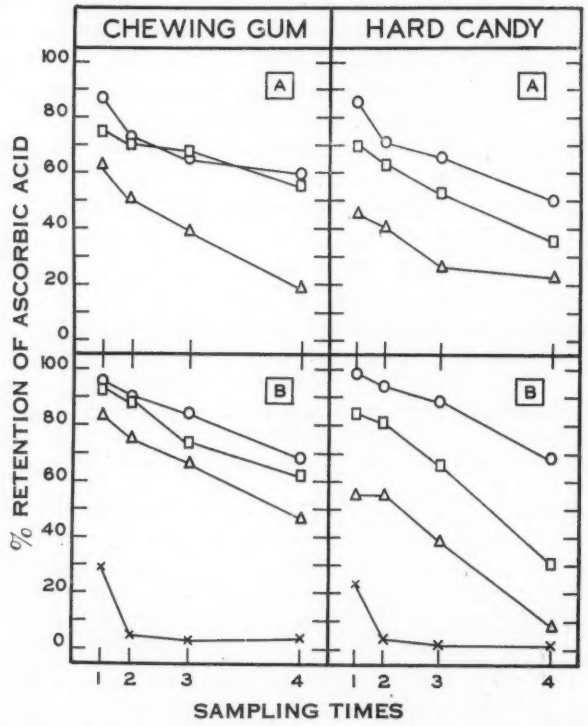

FIG. 1. *The effect of conditions of storage on the stability of ascorbic acid in fortified chewing gum and candy.*

A. Average effect of temperature for all humidities.
○ = *15.6° C.*; □ = *23.9° C.*; △ = *37.8° C.*

B. Average effect of relative humidities for all temperatures.
○ = *sealed containers*; □ = *50% R.H.*; △ = *75% R.H.*; × = *95% R.H.*

Sampling times: 1 = 6 wk.; 2 = 3 months; 3 = 6 months; 4 = 1 year.

was improved as a result of experience gained in processing technique. Losses of ascorbic acid from the gum tablets were somewhat less than from the candy at 50 and 75% relative humidity, but are greater in dry storage. The light coating of wax on gum tablets no doubt rendered them less hygroscopic at the intermediate conditions.

In these experiments no significant differences in ascorbic acid retention were found between materials stored in air and in carbon dioxide.

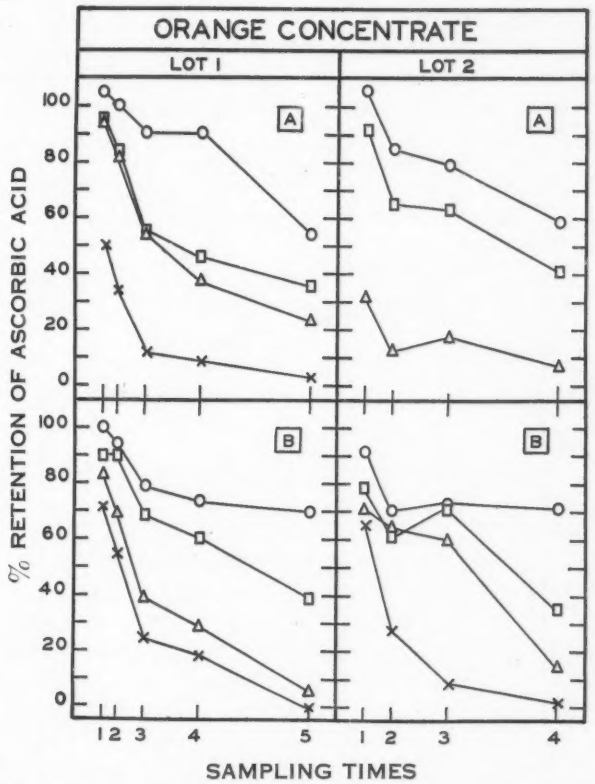

FIG. 2. *The effects of conditions of storage on the stability of ascorbic acid in natural orange concentrate.*

A. Effect of temperature averaged for all humidities.
Lot 1: ○ = −1.1° C.; □ = 15.6° C.; △ = 23.9° C.; × = 37.8° C.
Lot 2: ○ = 15.6° C.; □ = 23.9° C.; △ = 37.8° C.

B. Effect of relative humidity averaged for all temperatures.
Lot 1: ○ = 20% R.H.; □ = 50% R.H.; △ = 75% R.H.; × = 95% R.H.
Lot 2: ○ = sealed containers; □ = 50% R.H.; △ = 75% R.H.; × = 95% R.H.

Sampling times.
Lot 1: 1 = 3 wk.; 2 = 6 wk.; 3 = 3 months; 4 = 6 months; 5 = 1 year.
Lot 2: 1 = 6 wk.; 2 = 3 months; 3 = 6 months; 4 = 1 year.

Ascorbic acid in the commercial tablets was 75% stable for three months under the most adverse conditions, but the losses from the 100 mg. units were greater than from those of lower potency (Fig. 3). Assuming that the same material was used as a binder for both tablets, there is no obvious reason for this difference. It is possible that the lower potency tablets were compressed to a greater degree and made less pervious to moisture.

The jams differ from the other materials in that they contain about 70% of solids as compared with about 96% in the gum and higher in the other materials. In six months the average loss from all four jams at 23.9° C. was about 25%. At higher temperatures the losses were sharply increased (Fig. 4, A). Losses of ascorbic acid from plum, peach, and raspberry jams did not differ significantly, but the average loss for these three was greater

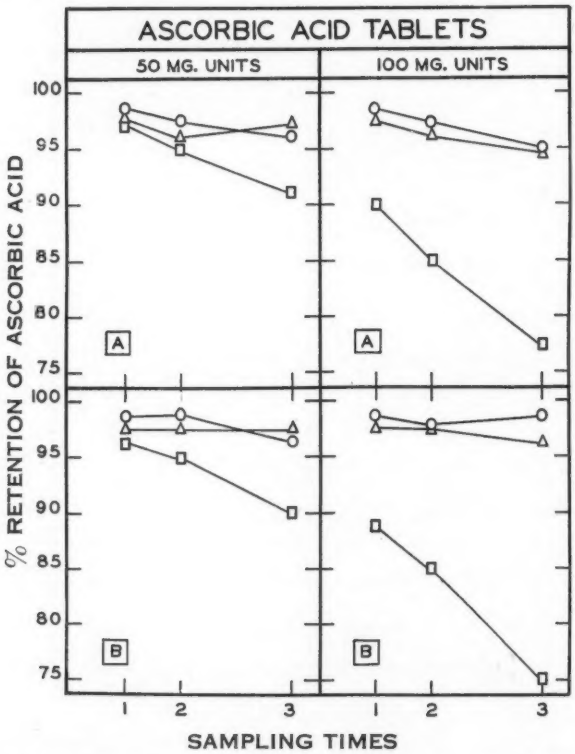

FIG. 3. *The effect of conditions of storage on the stability of ascorbic acid in commercial tablets.*

A. Effect of temperature averaged for all humidities.
○ = *15.6° C.*; △ = *23.9° C.*; □ = *37.8° C.*

B. Effect of relative humidity, averaged for all temperatures.
○ = *stored in vials*; △ = *50% R.H.*; □ = *75% R.H.*

Sampling times: 1 = 3 wk.; 2 = 6 wk.; 3 = 3 months.

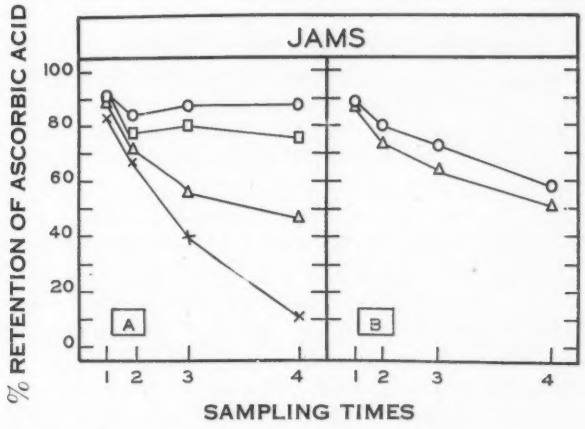

FIG. 4. *The effect of conditions of storage on the stability of ascorbic acid in fortified jams.*
A. Effect of temperature averaged for all jams.
○ = 15.6° C.; □ = 23.9° C.; △ = 37.8° C.; × = 43.3° C.
B. ○ = average of strawberry jams for all temperatures; △ = average of plum, raspberry, and peach jams for all temperatures.
Sampling times: 1 = 3 wk.; 2 = 6 wk.; 3 = 3 months; 4 = 6 months.

than the average for strawberry jam (Fig. 4, B). These results should not be interpreted as necessarily applicable to jams to which ascorbic acid has been added during processing.

Conclusions

Ascorbic acid may be successfully incorporated in a number of materials, and preserved in them without appreciable loss under certain conditions of storage. Temperatures in excess of 23° C. and exposure to moist atmospheres favour rapid destruction of ascorbic acid. With protection from moisture, materials such as hard candy and tablet form chewing gum retain much of the added ascorbic acid at higher temperatures for periods up to one year. During storage at 23.9° C. for six months, fortified jams retain 75% of the ascorbic acid incorporated after the commercial processing has been completed.

Acknowledgments

The authors are indebted to the Standing Committee on Nutrition (Army) for permission to include the data from the jam storage experiment, which was undertaken at its request. They also wish to express their appreciation of the co-operation of the firms who supplied the materials used in this investigation and to acknowledge the assistance of Miss J. R. Lewis, and Mr. J. Creasy, Laboratory Assistants.

References

1. BERGNER. Z. Untersuch. Lebensm. 81 : 497. 1941. *Abstracted in* Nutrition Abstracts and Reviews, 12 : 412. 1943.
2. HOPKINS, J. W., MARSHALL, J. B., and CREASY, J. C. In preparation.
3. RAUCH, G. H. Food Manuf. 17 : 34. 1942.

DRIED WHOLE EGG POWDER

XI. OCCURRENCE AND DISTRIBUTION OF *SALMONELLA* ORGANISMS IN CANADIAN POWDER[1]

By N. E. Gibbons[2] and R. L. Moore[3]

Abstract

Salmonella organisms have been isolated from 28 of 380 samples of Canadian dried egg powder. Nine types were found: *S. bareilly, S. pullorum, S. oranienburg, S. typhi-murium, S. thompson, S. minnesota, S. newport, S. manhattan,* and *S. potsdam.* In the first grade powder *Salmonella* organisms were found more frequently during the warm months. A greater percentage of second grade powder was contaminated than of first grade. The number of organisms was usually small. Of 21 samples on which *Salmonella* counts were made, 13 contained less than one organism per gram, seven between one and 10, and one, 54 per gram. In two carlots the distribution of *Salmonella* organisms was irregular.

Introduction

The possible presence of pathogenic organisms in egg powders is a potential health hazard that has been viewed with considerable concern by some authorities. Organisms of the enteric group, particularly *Salmonella*, may be introduced by human carriers or by contaminated eggs. Although no reference has been found to the presence of *Salmonella* organisms other than *S. pullorum* in hens' eggs, the isolation of *S. give* from an egg-nog that was responsible for several cases of food poisoning has been reported (24). However, from the report of the outbreak (20) it was impossible to decide whether the eggs could be considered as the source of the organisms. Although as yet eggs have not been incriminated, there is a growing literature on the types of *Salmonella* isolated from fowl (5, 7, 8, 16, 18, 19) and, as Schrader (23) points out, eggs might carry the organisms. The presence of *Salmonella* strains in dried egg powder has also been reported (2, 24).

Canadian egg powder produced from November, 1942, to the end of December, 1943, has been examined for the presence of organisms of the genus *Salmonella* and the present paper is a summary of these findings.

Material and Methods

For grading purposes samples of egg powder are set aside hourly by the drier and at least 2% of each day's production is sampled by a resident government inspector; the resulting composites are submitted for analysis. During the first part of the investigation each composite was blended before examination by turning it over several times on sterile paper. Later the samples,

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[2] *Bacteriologist, Food Investigations.*

[3] *Laboratory Assistant, Food Investigations.*

as received, had already been passed at least twice through a sterile flour sifter. While this method of sampling may be considered to represent the carlot, it is evident that negative results on such small samples cannot be taken as evidence that *Salmonella* organisms are absent.

Tetrathionate broth (Difco) has been used throughout as an enrichment medium. In the early work duplicate 5 gm. lots of powder were suspended by grinding them in a mortar with 45 ml. of water. From each, 25 ml. (2.5 gm. of powder) was added to 25 ml. of double strength tetrathionate broth. Later (June) it was found simpler to add 5 gm. of powder directly to 100 ml. of tetrathionate broth. Quadruplicate samples (i.e. 20 gm. of powder in all) were prepared and incubated 18 to 24 hr. at 37° C.

Several of the differential plating media referred to in the recent literature were tried. Of these desoxycholate citrate and SS (Difco) seemed the most suitable and for the routine examinations the latter was adopted. Plates were streaked from the tetrathionate broth and incubated overnight at 37° C.

In egg powder, as in faecal material, organisms of the coliform and *Proteus* group complicate the isolation of pathogens. However, with the exception of an occasional slow lactose fermenter they gave little trouble. One very common type produces colourless colonies that, on touching with the needle, are mucoid or viscid and are easily avoided. These produce acid and gas slowly from lactose and may or may not ferment sucrose. *Proteus* colonies are indistinguishable from *Salmonella* and at first the simplest method of distinguishing *Proteus* was to fish them into sucrose broth and where possible tryptone broth. Those organisms fermenting sucrose and those producing indol were eliminated. It was noted that when *Salmonella* occurred these interfering organisms were usually excluded or in the minority on SS agar plates after enrichment in tetrathionate broth. Gram negative, motile rods that produce acid and gas from dextrose, do not attack lactose, sucrose, or salicin, and do not produce indol were taken as members of the *Salmonella* group. Organisms that were non-motile and did not ferment maltose were classified as *S. pullorum*. All others have been typed by Dr. P. R. Edwards and all but one submitted on the basis of the above criteria were *Salmonella*.

Carlots of powder suspected of containing *Salmonella* organisms were held pending further investigation and since three days were required to eliminate *Proteus* and longer to establish the presence of *Salmonella*, the use of O-sera was adopted for more rapid identification. Eight sera (O1, O2, O4 to O9) were used (9). By this means members of the *Salmonella* group could usually be identified directly from the SS agar plates.

During the last seven months, an attempt was made to estimate the number of *Salmonella* organisms in all samples in which they were detected. Thirteen grams of powder were ground in a mortar with sand and 117 ml. of tetrathionate broth. This is sufficient to give 10 tubes each of 10, 1.0, and 0.1 ml. (i.e. 1.0, 0.1, and 0.01 gm. of powder). Tetrathionate broth (1 to 2 ml.) was added to each tube containing 0.1 ml. of suspension. After incubation, tubes positive for *Salmonella* were determined by streaking the broth on

SS agar and checking colourless colonies for the group previously found. The most probable number (*M.P.N.*) per gram was calculated by considering the 10 tubes as duplicate sets of five and the most probable numbers for the two sets were averaged. Using the tables given for 100 ml. of water (1), the most probable number of organisms per gram of powder is the value given divided by 10.

Results

From November 24, 1942, to December 31, 1943, samples from 380 lots of powder were examined and *Salmonella* types found in 28 (7.37%). The data are summarized in Table I.

Changes in the requirements altered the classification of powders produced after April (3). Grade A powder was made up of powder from the main drying chamber and any secondary collector powder that met the grade requirements. Grade B powder usually consisted of collector powders, screenings, etc. Before the powders were graded 113 samples had been examined and *Salmonella* found in five (4.4%). In subsequent work 13 of the 204 lots of Grade A powder (6.3%) and 10 of 63 lots of Grade B powder (16.0%) contained *Salmonella* organisms. Four of the positive ungraded and three of the Grade B samples were from the same plant (*F*) and all contained the same type.

Nine types of *Salmonella* were found: *S. bareilly* in 11 lots, *S. pullorum* in five, *S. oranienburg* in four, *S. typhi-murium* in three, *S. thompson* in two, *S. minnesota* in two, and *S. newport*, *S. potsdam*, and *S. manhattan* in one lot each. With the exception of *S. bareilly*, *S. pullorum* was found most frequently although it might be expected even more often. The occurrence of *S. potsdam* is of interest since this is the first time, to our knowledge, that it has been reported in America (6).

In only one carlot (*AB*2) were two types found (*S. pullorum* and *S. minnesota*). Since only group sera were available it was not possible to distinguish types within groups. More intensive studies would probably yield interesting results.

As seen from Table I the number of *Salmonella* organisms in the powder is usually low. Of 21 samples on which estimates were obtained, 13 contained less than one organism per gram, seven contained between one and 10, and one, 54 per gram. On recounting, considerably fewer organisms were always found, reflecting the rapid rate at which the organisms die off on storage. This point will be considered more fully in a subsequent paper (10).

There is little relationship between the total viable count, coliform and *E. coli* content*, and the presence of *Salmonella* organisms (Table I). Coliforms were detected in brilliant green bile broth and the presence of *E. coli* was confirmed on eosin methylene blue agar. Sample *HA*3(*i*) had a viable

* *The majority of these counts were made by, and are reported through the courtesy of Dr. C. K. Johns, Division of Bacteriology, Central Experimental Farm, Ottawa, who took over the testing of powders for grading purposes.*

TABLE I

TYPES OF *Salmonella* ISOLATED FROM 28 SAMPLES OF DRIED EGG POWDER

Plant	Grade and carlot No.	*Salmonella* type	*M.P.N.** per gram	Total viable count, thousands/gm.	Total microscopic count, thousands/gm.	No. of tubes showing coliforms**	No. of tubes showing *E. coli****
A	A 1	*S. typhi-murium*	<0.1	41	880	10	6
	A 2	*S. bareilly*	0.1	15	220	10	10
	A 3	*S. minnesota*	<0.1	12	110	2	2
	B 1	*S. typhi-murium*	>1.0	140	—	10	10
	B 2	*S. minnesota*	<0.1				
		S. pullorum	0.1	130	330	2	2
B	A 1	*S. oranienburg*	0.1	21	880	8	8
	A 2	"	0.2	91	6 0	2	0
	A 3	"	0.6	52	220	2	0
C	Not graded 1	*S. manhattan*	—	147	—	—	5
	A 1	*S. pullorum*	—	30	—	2	2
D	A 1	*S. newport*	0.2	490	—	5	4
F	Not graded 1	*S. bareilly*	—	1300	—	10	7
	2	"	—	1300	—	10	10
	3	"	—	193	—	9	1
	4	"	—	280	—	6	0
	B 1	"	>1.0	8400	—	10	4
	2	"	2.0	280	—	10	6
	3	"	4.0	5600	4400	10	10
G	B 1	*S. pullorum*	—	75	—	2	0
H	A 1	*S. pullorum*	—	450	—	0	0
	A 2	*S. bareilly*	6.0	91	770	0	0
	A 3(*i*)	*S. bareilly*	9.0	2	110	0	0
	(*ii*)	*S. thompson*	0.4	240	440	10	2
	(*iii*)	"	0.2	140	330	2	0
	A 4	*S. bareilly*	54.0	92	550	2	2
	B 1	*S. potsdam*	0.05	1800	—	10	0
	B 2	*S. thompson*	9.0	460	1100	10	0
I	A 1	*S. oranienburg*	0.5	170	660	10	10
	B 1	*S. pullorum*	—	50	—	0	0
	B 2	*S. typhi-murium*	<1.0	300	—	0	0

* *M.P.N. = most probable number of organisms.*

** *Ten tubes of 1/100 dilutions of Grade A powders and 1/1000 dilutions of Grade B powders were tested.*

*** *The presence of E. coli was confirmed on eosin methylene blue agar.*

count of only 2000 per gm., yet a *Salmonella* count of nine per gm. when analysed. On the other hand Lot *FB*3, with a viable count of 5,600,000, contained four *Salmonella* per gm. and *HB*1, with a viable count of 1,800,000, contained less than one per gm. *Salmonella* organisms were not detected in

the sample having the highest count obtained during the year (8,700,000 per gm.).

It is also evident that there is no relation between the number of coliforms or *E. coli* present, since *Salmonella* organisms have been detected in powders in which the presence of *E. coli* has been confirmed in all of 10 tubes and also in powders in which none of the tubes showed gas.

From June until September there was a steady increase in the percentage of positive samples found in Grade A powder (Table II). This is apparently due to a combination of warm weather and the necessity of using frozen eggs as early as July (Table III). No doubt the opportunity for growth of bacteria is enhanced during thawing operations.

TABLE II

SEASONAL DISTRIBUTION OF *Salmonella*-POSITIVE SAMPLES ARRANGED BY MONTH OF PRODUCTION

	Grade A powder			Grade B powder		
	No. samples	No. positive	% Positive	No. samples	No. positive	% Positive
Nov.-March	116*	5	4.3	4	0	0
April	28	1	3.6	5	0	0
May	29	0	0	15	0	0
June	42	2	4.8	13	4	30.3
July	34	2	6.0	10	3	30
Aug.	19	2	10.5	6	1	16.6
Sept.	14	3	21.4	2	0	0
Oct.	11	2	18.2	1	0	0
Nov.	17	1	5.9	2	1	50
Dec.	7	0	0	5	1	20
	317	18	5.67	63	10	15.8

* *One hundred and thirteen samples were not graded, five of these positive.*

TABLE III

CARLOTS OF GRADE A POWDER, CONTAINING *Salmonella* ORGANISMS, PRODUCED FROM SHELL, MIXTURES OF SHELL AND FROZEN, AND FROM FROZEN EGG FROM APRIL TO DECEMBER

	Shell		Shell + frozen		Frozen	
	No. cars	No. positive	No. cars	No. positive	No. cars	No. positive
April	28	1	0		0	
May	29	0	0		0	
June	42	2	0		0	
July	24	2	9	0	1	0
Aug.	6	1	5	1	8	0
Sept.	1	0	3	2	10	1
Oct.	2	0	0	0	9	2
Nov.	0	0	1	0	16	1
Dec.	0	0	2	0	5	0
	132	6	20	3	49	4
	4.5%		15%		8%	

A greater percentage of Grade A samples dried by the plants in the prairie provinces was positive than of those dried by the eastern (Ontario) plants (Table IV). This would have been true of the B grade powder as well except for one plant (*F*). More types of *Salmonella* were also found in the western plants.

TABLE IV

DISTRIBUTION OF *Salmonella*-POSITIVE SAMPLES BY PLANTS FOR CARLOTS PRODUCED DURING 1943 CONTRACT YEAR

Plants	Grade A powder			Grade B powder			Types of *Salmonella* isolated
	Carlots produced	Lots positive	% Positive	Carlots produced	Lots positive	% Positive	
Eastern							
F	22	1	4.5	4	3	75.0	*bareilly*
E	15	0	0	0	0	0	
D	13	1	7.7	2	0	0	*newport*
C	49	1	2.0	6	0	0	*pullorum*
	99	3	3.0	12	3	25.0	
Western							
H	29	4	13.8	17	2	11.7	*pullorum, potsdam, bareilly, thompson*
G	11	0	0	5	1	20.0	*pullorum*
I	20	1	5	13	2	15.4	*pullorum, typhi-murium, oranienburg*
A	20	2	10	5	2	40.0	*pullorum, typhi-murium, bareilly, minnesota*
B	53	3	5.7	9	0	0	*oranienburg*
	133	10	7.5	49	7	14.3	
Total	232	13	5.6	61	10	16.4	

It has been possible to check the distribution of *Salmonella* organisms in two carlots. Lot *HA*2 was produced between August 12 and 16, during which time shell eggs were dried, and between September 8 and 17, when frozen eggs were dried. When examined on September 28 the composite sample contained approximately six organisms per gram. The car was resampled on October 15 and a total of 37 samples were taken, two or three separate lots being obtained from each day's production. On checking duplicate 5 gm. aliquots from each sample, *Salmonella* organisms were found in only one of the three samples from the first day's production. On repeating the test, using four 5 gm. aliquots, they were detected in two of the first day's samples. The numbers were approximately four and nine per gm. The second carlot, *HA*4 was produced during October 10 to 16, 20, 26 to 28, 31, and November 1 and 2. The composite sample examined on November 8 contained approximately 54 organisms per gm. The powder was stored from November 3 to December 14 at 46° F. Samples were taken on December 23 when the temperature was 62° F. When examined five days later, 10 lots (10-gm. samples)

of the first seven days' production were found to contain *Salmonella*. Repeats using 20-gm. amounts increased this to 13 lots. The distribution is shown in Table V. Repeats with 30 gm. samples were again negative on lots in which *Salmonella* did not occur in the first test.

TABLE V

THE DISTRIBUTION OF *Salmonella* IN CARLOT *HA*4

Date	No. of samples	No. positive	*M.P.N.**/gm.
Oct. 10	3	2	0.1
11	3	1	<0.1
12	3	3	<0.1, 0.1, 12.5
13	3	0	
14	3	2	<0.1, <0.1
15	3	2	0.4, 2.0
16	3	3	1.0

* *M.P.N. = most probable number of organisms.*

Although some time had elapsed in both carlots, between the initial and final sampling, it is evident that to give the numbers originally found in the composite sample, even allowing for the presence of a few in the negative samples, a large number must have been present in some portions of the carlot. It is also evident from such irregular distribution that although samples are reported as negative, *Salmonella* organisms may possibly be present in the carlot.

In Lot *HA*4 the original viable count was 92,000 per gm. At the final sampling the average of six lots of *Salmonella*-containing powder was 39,500 per gm. and of four lots of negative powder 43,000 per gm. This indicates a reduction of slightly more than 50%. At the same time the *E. coli* content decreased from approximately 20 to less than two per gm.

Plant *F* has been mentioned previously and is the only plant in which only one type, *S. bareilly*, was repeatedly isolated from the powder. Because of this a carrier was suspected as the source of contamination. Although tests were made on three different occasions *Salmonella* could not be detected in the stools of anyone who had had contact with the melange or powder over the whole period. It would therefore seem that either the eggs being supplied this plant were contaminated with *S. bareilly* or it was being carried in the plant. Since the sanitary condition of the plant is good the latter does not seem possible. This is further borne out by the isolation from the high pressure pump of an organism that agglutinated with No. 4 serum and was assumed to be *S. bareilly*. The organism was typed as *S. oranienburg* and since this type had not previously been found inquiries were made and it was found that the eggs being dried on that particular day had been brought in from a western province. Owing to some inherent peculiarity in the drying chamber of this plant, powder and liquid are blown back and collect as a

moist lump above the spray nozzle. This lump being moist and warm is ideal for bacterial growth. Periodically it breaks off, and is a source of contamination for the rest of the powder.

A further indication that the eggs are probably a source of contamination is provided by car *HA3*. Three samples (*i*, *ii*, *iii*), which had been dried in immediate succession, were received and *Salmonella* types agglutinating with No. 4 sera were isolated from each. That isolated from Lot (*i*) was typed as *S. bareilly* while those from the other two lots were *S. thompson*. The eggs for Lot (*i*) had been broken and dried immediately in the plant. Lot (*ii*) had been broken in the same plant previously and frozen and stored for a time. Lot (*iii*) was made from frozen eggs that had been broken and stored in an adjoining province.

Discussion

The source of members of the *Salmonella* group in egg powder is not definitely known. With one exception all of the types isolated have been reported in fowl in the United States (8). The finding of *S. oranienburg* in Plant *F* when drying western eggs, and of different types in Carlot *HA3* in batches produced from eggs from different provinces, points to the eggs as the source. Some experimental evidence is also available that it might come from faecal contamination on the shell of the egg. Schalm (22) demonstrated that an organism of the *typhi-murium* group could survive on the shell when added in faecal matter and would also penetrate into the egg. *S. pullorum*, of course, may also come from infected yolks. Hinshaw (11) found *S. typhi-murium* in the ovaries of reacting turkeys and mentions similar findings by other workers. He also mentions the possibility of eggs becoming contaminated by faecal matter. Most of the organisms in egg liquid originally come from the shell. Johns (15) has shown that even in storage eggs the number in the liquid on breaking is usually low. Since the number of *Salmonella* organisms introduced at this time must also be low considerable multiplication must be assumed after breaking in order to account for the numbers found in powder. The finding of *Salmonella* in only the first day's production in Carlot *HA2* might be taken as indicating a pocket, not properly cleaned out, in which multiplication occurred and which was washed out by the liquid egg when operations were again started. On the other hand, as previously mentioned, there may be opportunities for multiplication as in Plant *F*, although as far as is known this situation is unique.

Because of the apparent irregular distribution in the powder, the numbers reported have little meaning. The small numbers found are, however, striking. Very little information is available regarding the minimal dose that will produce symptoms in humans. Hormaeche *et al.* (13) fed five human volunteers from 2000 to 4000 million organisms of a strain of *S. typhi-murium*, isolated from a fatal case in a six-months-old child, and produced mild to fairly severe reactions of not more than three days' duration. Dack (4) states that, "Salmonella infection of the food poisoning type is caused by the ingestion of large numbers of salmonella organisms." Savage (21)

presents some evidence that with *S. paratyphi B* infection the more massive the dose the shorter the incubation time. Verder and Sutton (25) present some similar evidence. Some of the earliest reports (reviewed by Dack (4)) indicate that some individuals are more susceptible than others. Hormaeche and his co-workers (12, 14) indicate that children are very susceptible to infection with many types of *Salmonella*. Kehr and Butterfield (17) recently advanced the theory that a small percentage of the population may be infected by a single typhoid organism. It is possible that a few individuals may be infected by the ingestion of small numbers of other members of the *Salmonella* group. Since little is known as to how few organisms will produce symptoms in normal individuals it is impossible to say whether the ingestion of less than 1000 organisms (the equivalent of one egg (12.5 gm.) of the worst powder (54 per gm.)), would constitute an infective dose. Although the amount consumed is small, it is of interest to note that taste panels have partaken of 'scrambles' of all of the positive powders with no ill effects. With proper cooking little danger exists (10). However, should the product be consumed raw, be improperly cooked, allowed to incubate after superficial cooking or consumed by susceptible individuals, the possibility of infection must be considered. There is also the possibility of powder, or reconstituted egg, in which multiplication has occurred, contaminating food that is consumed raw or has already been cooked.

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References

1. American Public Health Association. Standard methods for the examination of dairy products. 8th ed. New York. 1941.
2. Bornstein, S., Saphra, I., and Strauss, L. J. Infectious Diseases, 69 : 59-64. 1941.
3. Can. Dept. Agr., Spec. Products Board Requirement No. 5. April 27, 1943.
4. Dack, G. M. Food poisoning. Univ. of Chicago Press, Chicago. 1943.
5. Edwards, P. R. Proc. World's Poultry Congr., 7th Congr., pp. 271-274. 1939.
6. Edwards, P. R. Personal communication. 1943.
7. Edwards, P. R. and Bruner, D. W. Am. J. Hyg. B, 34 : 121-124. 1941.
8. Edwards, P. R. and Bruner, D. W. J. Infectious Diseases, 72 : 58-67. 1943
9. Edwards, P. R. and Bruner, D. W. Univ. Kentucky Agr. Expt. Sta. Circ. 54. 1942.
10. Gibbons, N. E. and Moore, R. L. Can. J. Research, F, 22 : 58-63. 1944.
11. Hinshaw, W. R. California Agr. Expt. Sta. Bull. 613. 1943.
12. Hormaeche, E. and Peluffo, C. A. Puerto Rico J. Pub. Health Trop. Med. 17 : 99-123. 1941.
13. Hormaeche, E., Peluffo, C. A., and Aleppo, P. L. Arch. urug. med. cir. espec. 9 : 113-162. 1936.

14. HORMAECHE, E., SURRACO, N. L., PELUFFO, C. A., and ALEPPO, P. L. Am. J. Diseases Children, 66 : 539-551. 1943.
15. JOHNS, C. K. Food in Canada, 3 : 15-16. 1943.
16. JUNGHERR, E. and CLANCY, C. F J. Infectious Diseases, 64 : 1-17. 1939.
17. KEHR, R. W. and BUTTERFIELD, C. T. U.S. Pub. Health Repts. 58 : 589-607. 1943.
18. LERCHE, M. Proc. World's Poultry Congr., 7th Congr., pp. 274-278. 1939.
19. MALLMAN, W. L., RYFF, J. F., and MATTHEWS, E. J. Infectious Diseases, 70 : 253-262. 1942.
20. NEW YORK CITY, DEPT. OF HEALTH. Personal communication. 1943.
21. SAVAGE, W. J. Hyg. 42 : 393-410. 1942.
22. SCHALM, O. W. J. Infectious Diseases, 61 : 208-216. 1937.
23. SCHRADER, J. H. Food control. Its public health aspects. John Wiley & Sons, Inc., New York. 1939.
24. SELIGMANN, E., SAPHRA, I., and WASSERMANN, M. Am. J. Hyg. 38 : 226-249. 1943.
25. VERDER, E. and SUTTON, C. J. Infectious Diseases, 53 : 262-271. 1933.

DRIED WHOLE EGG POWDER

XII. THE EFFECT OF DRYING, STORAGE, AND COOKING ON THE *SALMONELLA* CONTENT[1]

By N. E. Gibbons[2] and R. L. Moore[3]

Abstract

Over 99% of the *Salmonella* organisms in liquid egg were killed on drying in an experimental spray dryer. Since comparable results are obtained in the experimental and commercial units with other organisms, and powders of similar quality are produced, it is deduced that most of the *Salmonella* organisms would also be destroyed in commercial dryers. On storage the organisms survive longer the lower the temperature. Even at 7.2° C. there was a 97% reduction in eight weeks and at −1.1° C. a 75% reduction in three months. Massive inoculations of *Salmonella* organisms in reconstituted egg were destroyed when cooked as scrambled egg, omelets, and in sponge cakes, custards, and muffins.

Introduction

Various *Salmonella* types have been reported in dried egg powder (1, 3, 6). It might be expected that very few of this group would survive the drying process and this is borne out by the numbers found (3). Whether a public health problem exists depends to a great extent on the survival of the organisms during storage and cooking. This paper deals with the effect of drying, storage, and cooking on the survival of *Salmonella* organisms in dried egg.

Material and Methods

To determine the effect of drying, fresh eggs were broken out, mixed, and strained. The melange was divided into two parts and one was inoculated with *S. manhattan* and the other with *S. bareilly* grown for 20 hr. in liquid egg at 20° C. Both cultures were isolated from egg powder. The melange was then dried in an experimental spray dryer (7). The air inlet temperature was 121° C. (250° F.). While drying melange containing *S. manhattan* the outlet air temperature started at 60° C. (140° F.) and gradually rose to 66° C. (150° F.), and with melange containing *S. bareilly* it was constant at 66° C. Between runs the dryer was washed and thoroughly steamed.

Viable counts were made on proteose-peptone, tryptone agar after incubation at 37° C. for 48 hr. The presence of *Salmonella* organisms in the powder was checked by adding known amounts to tetrathionate broth, incubating the cultures at 37° C. overnight, and then inoculating Kligler's agar (Difco). Since other hydrogen sulphide producing bacteria were absent from the original melange, as indicated by negative results in Kligler's agar after the enrich-

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[2] *Bacteriologist, Food Investigations.*

[3] *Laboratory Assistant, Food Investigations.*

ment of 25 ml. amounts of the melange in tetrathionate broth, the production of hydrogen sulphide indicated the presence of *Salmonella*. At first 12 gm. was ground with 108 ml. of tetrathionate broth and 10 tubes each of 10, 1.0, and 0.1 ml. were used to determine the most probable number (*M.P.N.*) (3). Later 30 and 40 1-gm. lots were used to determine the *M.P.N.*

No powders naturally contaminated with a reasonable number of *Salmonella* organisms could be obtained for storing, so powder with a high count was prepared artificially. Melange inoculated with *S. bareilly* was dried *in vacuo* over calcium chloride and mixed with a spray-dried product having an original moisture content of 4.1%. The contaminated powder contained some 4,000,000 organisms per gm. and the final material was produced by making serial dilutions. The original inoculum (1 gm.) was added, with a similar amount of sterile charcoal, to 100 gm. of spray-dried powder and put through a flour sifter. The charcoal seemed evenly distributed on the fourth sieving but it was continued for four more. All subsequent dilutions were also sieved eight times. The number of *Salmonella* organisms was checked by enrichment in tetrathionate broth followed by inoculation into Kligler's agar and streaking on SS agar plates. There was good agreement between the two methods and since no hydrogen sulphide producers were found in 10-gm. lots of the original powder, Kligler's iron medium was used for the stored material. The powder was stored at 37°, 20°, and 7.2° C. (45° F.) and examined at intervals up to eight weeks.

For the cooking tests the powder was reconstituted in a Waring blendor with water in the proportion of one part of powder to three parts of water, and inoculated with the test organism. For scrambled eggs and omelets the contaminated egg was made up into a standard recipe used for taste panels (50 ml. reconstituted egg, 20 ml. milk, 10 gm. butter, and 1 gm. salt) and the equivalent of four eggs was cooked in a cast iron frying pan. The time of cooking and the temperature reached depend on the original temperature of the pan. Sponge cakes were made from a standard recipe (50 ml. reconstituted egg, 40 gm. sugar, 40 gm. flour) and all were baked at 190° C. (374° F.) for 45 min. Custards (5) and muffins (4) were made from formulae recommended for dried egg.

In the first test a suspension of *S. bareilly* was used to give a count corresponding to 8000 per gm. of dried egg. The eggs were scrambled in 15 min. reaching a maximum temperature of 68° C.; the omelet was cooked in 15 min. reaching a maximum temperature of 92° C. (197.6° F.) at the top and 98° C. (208.4° F.) at the bottom; sponge cakes were baked in a small experimental bread tin (10 × 6 × 5 cm.) and a large cake tin (22 × 22 × 3 cm.).

The tests were repeated using heavier inocula. One batch that was prepared had a final concentration corresponding to 2,000,000 *S. oranienburg* organisms per gm. and the other had 5,600,000 *S. typhi-murium* per gm. Such numbers may be reached if the reconstituted egg were held overnight at temperatures around 21° C. (unpublished data). These mixes were cooked more rapidly

(scrambled in three minutes, max. temp. 82° C. (179.6° F.); omelets four to five minutes, max. temp. 94 to 98° C.). The cakes were made as before.

Since the above cakes were small, the same recipe was used to make larger ones (19 × 9 × 6 cm.) more comparable to those made in commercial practice and offering greater resistance to heat penetration. To ensure rising and the resulting insulation baking powder was added to the sponge. The inocula (0.1 ml. of culture, corresponding to 700 *S. typhi-murium* at each point in one cake and 500 *S. oranienburg* in the other) were added by means of a syringe as nearly as possible to the geometric centre and to the middle of each end.

To determine the survival of *Salmonella* organisms all of the scrambled egg or omelet was dispersed in approximately 400 ml. of tetrathionate broth in a Waring blendor and added to the remaining part of 1 litre of tetrathionate broth so that it was cooled fairly rapidly. After incubation platings were made on SS agar. In the first two experiments the whole cakes were likewise dispersed and cultured. With the larger cakes, portions around the site of inoculation were removed after baking and cultured as before.

The first custards prepared were contaminated by adding between 10,000 and 100,000 *S. bareilly* or *S. typhi-murium* organisms to the reconstituted egg necessary for 750 ml. of formula. The milk was added hot (80°C.(176°F.)), the mix poured into individual cups (120 ml.), the cups placed in hot water (80° C.), and baked 35 min. These custards were not firm when removed from the oven and were definitely underdone. Larger custards were also made by baking 500 ml. of mix in a 2 litre beaker. Both of these batches were cooled in cold water and half cultured immediately and half incubated overnight at 37° C. The individual custards were cultured in 300 ml. of tetrathionate broth, half of the large custards in 750 ml.

Using the same recipe, custards were prepared in individual cups using hot and cold milk. The temperature of those made with cold milk was 18° C. (64.4° F.) and of those made with hot milk, 57° C. (134.6° F.). Three of each six were inoculated in the centre by means of a pipette with 0.1 ml. of a suspension of *S. bareilly* (17 million) and three with *S. typhi-murium* (20 million). All were placed in hot water (80° C.) and baked 45 min. at approximately 130° C. (266° F.). Each custard was cultured in 300 ml. of tetrathionate broth.

A large custard (500 ml.) was made with milk at 35° C., inoculated with 65,000,000 *S. typhi-murium* organisms and baked 45 min. with an oven temperature of 140° C. (274° F.). The centre portion was added to 750 ml. of tetrathionate broth.

The first muffins were contaminated by adding between 10,000 and 100,000 *S. bareilly* or *S. typhi-murium* organisms to the egg and mixing with the other ingredients. These were baked 20 min. in an oven preheated to 210° C. (410° F.). In the second lot each muffin was inoculated in the centre by means of a syringe with 0.2 ml. of a suspension of *S. bareilly* (12 million) or of *S. typhi-murium* (13 million). These were baked as before. For culturing,

two muffins were dispersed with 300 ml. of tetrathionate broth in a Waring blendor and incubated overnight.

Results

The Survival of Salmonella Organisms During Spray Drying

The reduction of *Salmonella* and other organisms during drying is shown in Table I. The percentage reduction is based on the fact that 1 gm. of powder is equivalent to 4 ml. of melange. It is evident that *S. manhattan* and *S. bareilly* are much more sensitive to the conditions of drying than the types represented in the viable count.

TABLE I

SURVIVAL OF *Salmonella* DURING SPRAY-DRYING

	Outlet air temp., °C.	Moisture content powder, %	Viable count		Reduction, %	*Salmonella, M.P.N.*		Reduction, %
			Melange/ml.	Powder/gm.		Melange/ml.	Powder/gm.	
S. bareilly	66	4.0	11.500	8.500	81.5	410	0.13	99.992
S. manhattan	60 – 66	4.2	11.500	16.300	64.6	5400	1.0	99.995

In the experimental dryer the temperatures of the outlet air and the air near the bottom of the cone are higher than in commercial dryers. However, in some commercial dryers using lower temperatures the percentage kill as determined by viable counts has been even higher (95%). It seems valid therefore to assume that the reduction of *Salmonella* organisms during drying will be comparable to that obtained in the experimental unit. It is evident with such reductions that to account for the number of *Salmonella* organisms found in commercial powder (3) the number originally present in the liquid egg must have been very high.

The Survival of Salmonella Organisms During Storage

Although the numbers present were small, the powder prepared in the previous experiment contained *Salmonella* organisms that had survived the drying operation. To determine the survival of such organisms this powder was stored at 23.9°, 20°, 15.6°, and 7.2° C. (75°, 68°, 60°, and 45° F.). In Table II are given the most probable numbers per gram based on enrichment cultures of 20 to 40 1-gm. lots of powder. In the powder originally containing one *S. manhattan* per gm. there is a definite increase in survival time as the storage temperature decreases. With less than one organism per gram, as is common in commercial powders (3), no organisms could be found in 30 gm. samples at two weeks even at the lowest storage temperature.

In the inoculated powder with an initial average content of 30 per gm. (range 13 to 54), the reduction on storage is more pronounced (Fig. 1). After storage at 37° C. no organisms could be detected in 10-gm. samples in three

TABLE II

SURVIVAL OF *Salmonella* IN SPRAY-DRIED POWDER DURING STORAGE, *M.P.N.* PER GRAM

Storage time	*S. manhattan*				*S. bareilly*			
	Temp. of storage				Temp. of storage			
	23.9° C.	20° C.	15.6° C.	7.2° C.	23.9° C.	20° C.	15.6° C.	7.2° C.
Orig.	1.0				0.13			
4 days	0.25				0.20			
1 week	0.10	1.30	0.10	0.90	0.12	<0.05	0.10	0.05
2 weeks	0.03	0.16	0.15	0.63	<0.03	<0.03	<0.03	<0.03
3 weeks	0.025	0.025	0.025	0.67	—	—	—	—
4 weeks	—	—	—	0.10	—	—	—	—

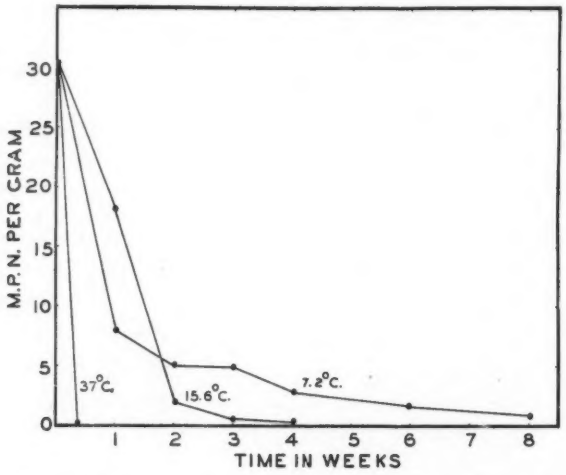

FIG. 1. *The survival of S. bareilly in egg powder stored at 37°, 15.6°, and 7.2° C. (most probable number per gram).*

days or in 20-gm. samples in five days. At 15.6° C. (60° F.) there was a decided decrease in number during the first two weeks and after four weeks, based on a 60 gm. sample, there were approximately 0.3 organisms per gm. (99% reduction). At 7.2° C. (45° F.) after an initial drop there was a more gradual decrease and approximately 0.8 organisms per gm. remained after eight weeks.

The powders prepared in making the serial dilutions for the above experiment were stored at −1.1° C. (30° F.). After three months, powder with an original *Salmonella* content of 40,000 per gm. contained approximately 1500 per gm. and one with 400 per gm. had fallen to approximately 100 per gm., a reduction of about 75% in both instances.

Effect of Cooking on the Salmonella Content of Egg Powder

In all cooking tests using reconstituted powder contaminated with large numbers of three of the most common types of *Salmonella* in egg powder, no *Salmonella* organisms could be detected in the cooked product. In making the custards it was observed that when hot milk was used many of the added organisms were killed before entering the oven. These results indicate that even large numbers of *Salmonella* organisms would be destroyed by ordinary, adequate cooking practices.

Discussion

Whether the contamination of egg powder with organisms of the *Salmonella* group can be regarded as a health hazard is debatable. The evidence presented shows that the danger is slight in well-cooked foods containing contaminated powder. It has been shown that the majority of the *Salmonella* organisms in melange are killed during drying, that many of those that survive drying die off during storage even at low temperatures, and that cooking will destroy massive inoculations. When found in Canadian egg powder, the number of *Salmonella* organisms has been small (3) and since several months usually elapse before consumption the number would be even less when the powder is used. Normal cooking will destroy the survivors.

The finding in man of *S. pullorum* (2) and other types of *Salmonella* common to fowl indicates that infection can occur from birds and the possibility of transmission by eggs and egg products must be considered. Reconstituted eggs might be consumed raw, as in egg-nog, and if made from contaminated powder and an incubation period were allowed between reconstitution and consumption, there is a possibility of infection. The reconstituted egg, or even the dry powder, might contaminate foods that have already been cooked or are eaten raw. The egg may also be used in dishes that are not subjected to the same heat treatment as the experimental trials and multiplication could occur both before and after cooking. It is felt, however, that such cases would be rare.

Acknowledgments

The assistance of Dr. A. H. Woodcock and Mr. H. Tessier of these laboratories, in drying the contaminated melange, is gratefully acknowledged.

References

1. Bornstein, S., Saphra, I., and Strauss, L. J. Infectious Diseases, 69 : 59-64. 1941.
2. Edwards, P. R. and Bruner, D. W. J. Infectious Diseases, 72 : 58-67. 1943.
3. Gibbons, N. E. and Moore, R. L. Can. J. Research, F, 22 : 48-57. 1944.
4. Jordan, R. and Sisson, M. S. U.S. Egg Poultry Mag. 49 : 218-221. 1943.
5. Jordan, R. and Sisson, M. S. U.S. Egg Poultry Mag. 49 : 266-269, 287-288. 1943.
6. Seligmann, E., Saphra, I., and Wassermann, M. Am. J. Hyg. 38 : 226-249. 1943.
7. Woodcock, A. H. and Tessier, H. Can. J. Research, A, 21 : 75-78. 1943.

THE STEREOGRAPH[1]

By R. H. Field[2]

Abstract

A compound stereoscope is described having facilities for (*a*) measuring parallax displacements and correspondence errors on vertical stereo air photographs, (*b*) measuring the rectangular co-ordinates of images on air photographs, (*c*) plotting air bases and minor control in strips of air photographs, (*d*) plotting to a predetermined scale planimetric detail in untilted or rectified vertical air photographs, (*e*) plotting form lines by the "floating mark" method.

Introduction

The mechanical linkage adopted in the Stereograph was proposed by Major General E. L. M. Burns, while he was in charge of the Geographical Section, General Staff, Department of National Defence, Ottawa, and Convener of the Instrument and Plotting Subcommittee of the Associate Committee for Survey Research. This linkage was devised as a result of a study of existing photogrammetric instruments, including experience with two following earlier designs proposed by General Burns (1, 2). Before relinquishing his post at Ottawa, General Burns made a Meccano model to illustrate his ideas. He left this in charge of the author, who prepared a complete design of the finished instrument. The Stereograph was finally built in the Instrument and Model Shop of the National Research Council from working drawings prepared in the Metrology Section.

The Stereograph in its completed form has the following features:

1. A Stereoscope (magnification 3.5×) which can scan the overlapped portion of a pair of stereo-photographs 10 in. × 10 in. or smaller.
2. Adjustment facilities for bringing a pair of photographs into correct relationship beneath the stereoscope.
3. Scales for measuring the X and Y co-ordinates of any point on either photograph.
4. Scale for measuring parallax displacements on the photographs.
5. Scale for indicating the length of the plotted air base.
6. Micrometers for measuring correspondence errors (perpendicular to the air base) of images registered on the two photographs.
7. Straight-edge to permit the ruling of air bases on the photographs.
8. Plotting table and pencil for plotting air bases and planimetric detail to any scale less than that of the photographs.
9. Viewing microscope for use alternatively with the pencil for setting purposes.

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Contribution from the Division of Physics and Electrical Engineering, National Research Laboratories, Ottawa, Canada. Issued as N.R.C. No. 1199.

[2] *Metrologist.*

General Scheme

The main plotting linkage, shown schematically in plan in Fig. 1, is based on the Zeiss parallelogram (3, 4). Each of the stereoscopic pair of vertical air photographs is clipped to a separate table, constrained by rails to move in a straight line (the "base" or X-direction of the machine). An arm, moving in a horizontal plane, has one end hinged to the table while the other end is guided so that the axis of the arm always intersects the fixed vertical axis of a pivot attached to the main frame.

The distance, perpendicular to the base direction, between the two pivot axes of the arms is D. The two arms are coupled by means of a "bridge" fitted with two pivotted "spiders" each consisting of a plate bearing three rollers, as indicated in the figure. The separation of the two spider axes, $l + b_p$ in the diagram, can be adjusted as desired. A third table, the plot table, also constrained to move in the base direction, is coupled by a strut to the support of the right spider. From the diagram it is evident that if the two photograph tables move together in the base direction through a distance x, the plot table will move through a distance $\frac{dx}{D}$, where d is the perpendicular distance from the line of the two fixed pivots to the line of the two pivots on the bridge.

In Fig. 1 the stereoscope is indicated by two pointers, representing the position of the intersection of the respective optic axes of the two telescopes with the photograph tables. The distance l, between these intersections, is constant and is made to be equal to the distance separating the fixed pivots of the two arms previously mentioned. The stereoscope is constrained by guide rails to move perpendicularly to the base direction. It also carries the hinge for one end of a third lever arm somewhat similar to those attached to the photograph tables, but shorter. This third arm operates a carriage moving over the plot table in the Y-direction, and which bears a pencil and viewing microscope. The point of contact between the third lever and the pencil carriage (actually a roller mounted on a small auxiliary carriage) is automatically maintained so that the ratios $\frac{d_1}{D_1}$ and $\frac{d}{D}$, on the diagram remain equal. An examination of the diagram will show that if the right stereoscope telescope be sighted on some part of a figure drawn on the right photograph table, and the fiducial mark in the telescope be made to trace the figure (using the X-motion of the photograph table and the Y-motion of the stereoscope) the pencil will trace the correct outline of the figure to the scale $\frac{d}{D}$.

In a pair of stereoscopic vertical air photographs the sum of the displacements of the two images of a point on the ground from the principal point, $b_l + b_r$ in Fig. 1, varies with the height of the camera lens above the point. Assuming level flight, the variation in this quantity for different points is a measure of the differences in ground elevation of the points (3). It follows that if the two photographs be separated so that, in Fig. 1, the two stereoscope

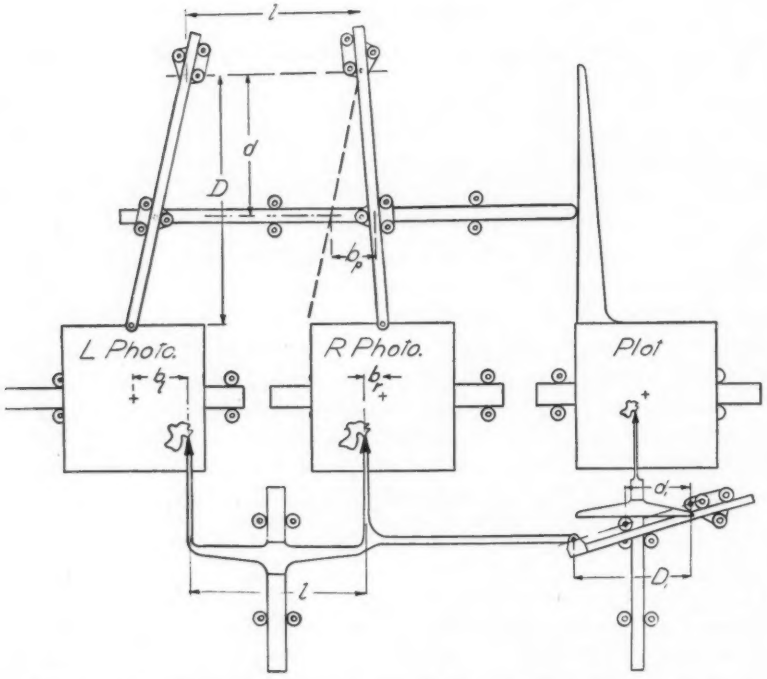

FIG. 1. *Scheme to illustrate the principles of the mechanical plotting linkage of the Stereograph, showing the Zeiss parallelogram for operating the plot in the X-direction and the lever attached to the stereoscope, which operates the pencil carriage in the Y-direction.*

l = *Separation of the fixed pivots for the parallelogram arms. This is equal to the projected spacing, in the plane of the photographs, of the fiducial marks in the stereoscope eyepieces.*

D = *Y-projection of the lengths of the parallelogram arms.*

D_1 = *X-projection of the length of the pencil carriage operating-lever.*

d = *Displacement of the parallelogram bridge pivots from the line joining the fixed pivots.*

d_1 = *Displacement of the point of contact between the single lever and the pencil carriage, from the fixed pivot of the lever.*

b_l = *X-co-ordinate of an image on the left photograph.*

b_r = *X-co-ordinate of the image of the same point on the right photograph.*

b_p = *The length of the plotted air base. (This is adjustable to suit the desired plotting scale.)*

telescopes are directed on to the respective images of the same point, and then be sighted on the images of a point at a different ground level, these second two images cannot both be brought simultaneously opposite the fiducial marks in the telescopes. This gives rise to the well known "floating mark" effect, where the observer seems to see the fused image of the two fiducial marks apparently poised in space above or below the landscape (3). Alignment can be restored (i.e., the floating mark again be made apparently to touch the ground) by changing the spacing of the two photographs. In the Stereograph this is done by moving the bridge in a direction normal to the

base direction and thereby altering the distances d and d_1. It is easily shown (3) that the consequent change in the ratio $\frac{d}{D}$ compensates for the variation in the photograph scale due to the difference of ground elevations, and therefore that the pencil will plot the orthogonal projections of the details photographed irrespective of the scale variations due to relief in a pair of untilted photographs exposed in the course of level flight. The scale of the plot depends on the displacement b_p of the bridge pivots beyond the fixed spacing l (3).

To operate the instrument, the left photograph table is moved by a screw actuated by a handwheel conveniently placed near the observer's left hand, a second screw with the handwheel controlled by the right hand governs the movement of the stereoscope, while the bridge is moved perpendicularly to the base direction by a third screw operated from a foot disk. These three movements cause the floating mark apparently to move in the X, Y, and Z directions respectively, relative to the landscape, as seen in a pair of correctly fused pictures.

Actual Instrument

While the mechanism just sketched is simple in principle, some thought was necessary before all the movements desired could be incorporated into a compact, easily built instrument. After the preliminary design had been worked out a full-scale wooden "mock-up" was built, and this facilitated progress in the completion of the design. The finished Stereograph is illustrated in Fig. 2. Some of its features are described below.

Photograph Holders

The photographs are held on pivotted duralumin platens, 10 in. square, by the aid of spring clips. A small hole, with witness marks, indicates the centre of rotation of each platen. It is quite easy to locate the photograph correctly on a platen by placing this hole beneath a fiducial mark in one of the stereoscope telescopes and then clipping the photograph so that its marked principal point is also beneath the fiducial mark. A clamp and spring-opposed slow motion screw permits each platen to be rotated through small angles for correct adjustment. Two knobs, conveniently placed at the front of the photograph carriage, control these adjustments, and a third operates a screw of 1 mm. lead which displaces the platen and its socket in a sense normal to the base direction. This is for the purpose of measuring or compensating correspondence errors due to tilt, but the graduated micrometer drum for this screw is always set to zero before a photograph is placed on the platen for adjustment.

The platen and other fittings are all mounted on a carriage supported by four rollers and constrained to move in the base direction by three other rollers engaging with a long rail fixed to brackets carried on the base casting of the machine. Journal type ball bearings are used for these rollers, which are mounted on eccentric pins for adjustment purposes. A ball bearing pivot

at the rear of each carriage is fixed to one end of the appropriate arm of the Zeiss parallelogram. The other end of the arm is supported by a roller and constrained in a horizontal plane by three other rollers, mounted on vertical pins. These four rollers are all fitted to a bracket pivotted on ball bearings so as to rotate about a fixed vertical axis on the main frame, as mentioned previously.

A scale beneath each carriage on the front supporting rail, with verniers attached to the carriages, permits the X-displacement of either carriage to be observed at any time. These two scales can be read to 0.1 mm., and a third, with vernier reading to 0.02 mm., is coupled at one end to the right carriage and slides in a tube, on which the vernier is mounted, attached to the left carriage. This scale measures the relative displacement of the two carriages (differential parallax), and to avoid unnecessary mental computation, or recording, a knob-controlled screw permits the vernier to be set when desired with its zero opposite a major graduation on the scale. Magnifying reader glasses, suitably mounted on pivots, permit all the verniers to be read from the observer's seat without eye-strain.

The left photograph carriage is coupled by a strut, having two pairs of helical closure springs, to a half nut on the X screw, which is operated through bevel gears from the left handwheel. A handle beneath the rails meshes or unmeshes the half nut into engagement with the screw, which runs in ball bearings. Thus, large movements can be given to the carriages by hand, and final adjustment made by the screw, after engaging the half nut.

Stereoscope

The four mirror scheme was adopted for the stereoscope, the mirrors being of stellite, polished optically flat on the front surface. They are each held at three points by spring-opposed screws, fitted so that adjustment can be made as desired without introducing any bending strains. Above the inner mirrors is a pair of telescopes for holding the floating mark, and magnifying the photograph. The telescopes present the images to the eyes at a convenient angle, 20° from the horizontal, which is attained by means of a pair of 20° roof prisms (which give the necessary image erection). Zeiss oculars, giving a reasonably good eye-space field of 70°, were fitted, and the rest of the optical parts were designed to take advantage of this angle. Actually the magnification is 3.5 diameters, and the field on a photograph covers 80 mm. diameter.

To permit adjustment to suit observers having different eye-spacing, the brackets carrying the inner mirrors and the telescopes are mounted on a dovetail slide. After adjustment the brackets can be clamped on the slide, and a small screw under each telescope tube permits the objective cell to be readily adjusted to compensate for the disturbance in focus arising from the change.

The diaphragms are optically flat glass disks spun into rings tapped for capstan screw centring in the usual manner. Fine lines were etched on the disks to form the fiducial marks, similar to those described in Reference (2).

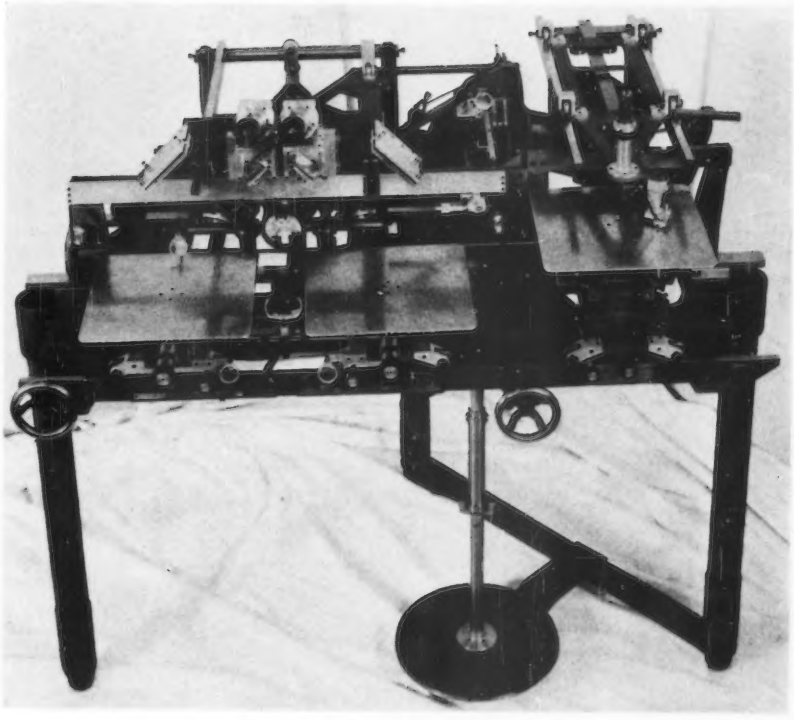

FIG. 2. *The Stereograph as completed.*

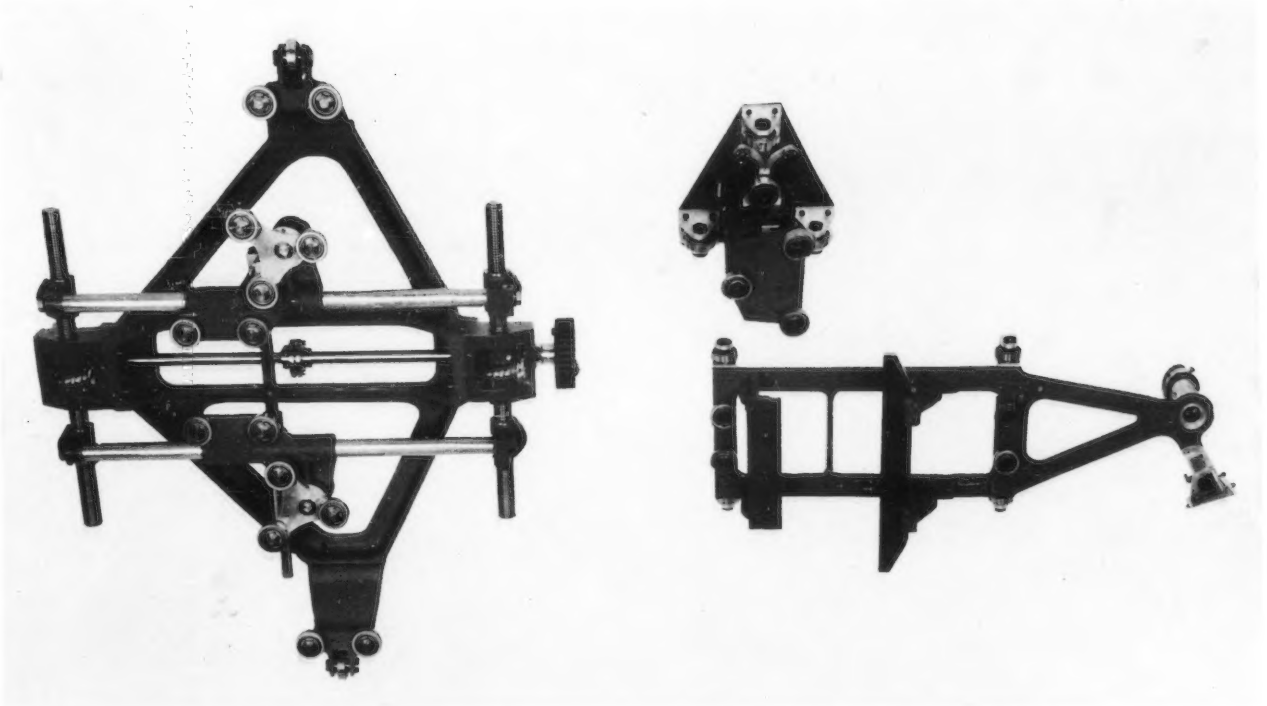

FIG. 3. *Left. The bridge from beneath. The two bright bars guide the bridge pivots, which are mounted on sleeves, whose position along the bars is controlled by the foot disk, via the two rollers beneath each sleeve. To the right is the knob controlling the spacing of the two guide bars and hence the plotting scale.*

Upper right. The auxiliary carriage which is fitted with the contact roller for the lever operating the pencil carriage. The position of this carriage along its guides is controlled by the foot disk.

Lower right. The pencil carriage, seen from beneath. To the left are the guide rails for the auxiliary carriage. To the right is the viewing microscope and the bracket carrying the pencil arm. In operation the auxiliary carriage fits on the pencil carriage at 90° from its orientation in the photograph.

A rail gantry, over the mechanism, acts as a support for the stereoscope carriage, which is of skeleton form and is borne and guided by ball bearing rollers. An extension of this carriage at the rear and to the right of the stereoscope carries the hinged end of the lever operating the plotting pencil, as well as the spring-closed strut coupling the carriage to a half nut on the Y screw. This nut may be engaged or released by a small lever on top of the stereoscope carriage, connected to a system of rods and bell cranks. The Y screw, operating the stereoscope is above the base frame of the Stereograph, and is coupled to the right handwheel by means of a shaft (beneath the frame) and spur gears at the rear.

Both X and Y nuts are opened by springs, the toggle action handles being used to pull the nuts into engagement. Struts are employed for coupling the nut housings and the part moved by either nut, to allow pulls or pushes being transmitted without any shear action. These couplings, together with the ball bearing rollers at the slides, cause the motion to be very smooth, and a minimum of effort is required to operate the various moving parts, even though backlash is practically eliminated.

Bridge

As explained previously, the function of the bridge is to couple the two Zeiss parallelogram arms attached to the photograph carriages, and to transmit their X movement (to scale) to the plot table. It also is used to determine the scale of the plot and to restore fusion in the stereoscope between the photographic images of points as the ground elevation of the actual points varies.

The main frame of the bridge, Fig. 3, is a lozenge-shaped aluminium casting supported at its right and left ends by brackets, each being fitted with a single roller to take the weight and two rollers to guide the movement in the base direction. A bracket at the rear with two rollers respectively above and below a horizontal rail provides the remaining necessary constraint to the bridge.

At the front and rear of the bridge-frame screws are fitted with their axes parallel to the base direction. The central bearing portion of each screw has a wormwheel keyed on it, and the two wormwheels engage with worms on a common shaft operated from a control knob situated at the front end of the bridge frame, above the photograph platens. The outer portions of each screw are threaded right hand and left hand respectively, with vee threads. The split nuts for these threads are connected by cylindrical rods, perpendicular to the base direction, so that when the control knob is rotated the spacing of the rods is adjusted while they always remain parallel. Thus is introduced the excess over the distance l (Fig. 1) which is the length of the plotted air base, b_p, and is indicated by a scale and vernier, read with the aid of the magnifier seen just above the left platen in Fig. 2.

Long sleeve brackets slide on the cylindrical rods, and each bracket is fitted with a vertical ball bearing spindle, at the lower end of which is a spider with three horizontal rollers to engage (two on one side and one on the other) with one of the arms hinged to the photograph carriages. An external

Upper right. The auxiliary carriage which is fitted with the contact roller for the lever operating the pencil carriage. The position of this carriage along its guides is controlled by the foot disk.

Lower right. The pencil carriage, seen from beneath. To the left are the guide rails for the auxiliary carriage. To the right is the viewing microscope and the bracket carrying the pencil arm. In operation the auxiliary carriage fits on the pencil carriage at 90° from its orientation in the photograph.

guide rail, parallel to the base direction, and moved parallel to itself by means of a screw operated from the foot disk, governs the position of the sleeves along their guide rods. Again horizontal ball bearing rollers on the sleeves are used as constraints. Rotation of the sleeve brackets about the rods is prevented by a rod fixed to one sleeve and passing through a hinged bracket on the other.

Plot Table

The plot table carriage is similar to the two photograph carriages, with the same form of clamp and tangent screw. No correspondence screw is fitted, but, instead, the platen is carried on a compound slide of simple construction having screw operation and spring closure and which is placed above the fixed pivot on the carriage. These adjustments permit the points already plotted from one pair of photographs to be set correctly when the succeeding pair is placed in position. It is essential, for correct performance of the machine, that the centre of rotation of the plot platen occupy a constant position with reference to the normal position of the centre of rotation of the right photograph platen, for a given bridge setting.

A scale, with vernier reading to 0.1 mm., to the left of the plot carriage is used to measure its displacement in the X-direction.

Pencil Carriage

A photograph of the pencil carriage, taken from the underside, is reproduced in Fig. 3. This carriage has four supporting rollers and four more to guide it in the Y-direction. The rollers engage with rails on a gantry over the mechanism, and the pencil and viewing microscope are mounted on a cantilevered portion of the carriage above the plot platen. Two rails, carried on brackets fastened beneath the pencil carriage serve as supports for the auxiliary carriage seen detached and placed just above the pencil carriage in Fig. 3. This carriage, equipped with ball bearing rollers at all contacts with other parts of the mechanism, has a single degree of freedom in the X-direction with respect to the pencil carriage, along the two underslung rails. At the bottom of the auxiliary carriage the three rollers seen nearest the pencil carriage in Fig. 3, engage with a rail, lying in the Y-direction and mounted on a sleeve which slides along a rod fixed to the frame of the machine. This sleeve is operated from the foot disk, the motion of the sleeve being in the X-direction. Thus when the bridge is moved by the foot disk to restore fusion, at the same time the auxiliary carriage is moved along the rails beneath the pencil carriage. A roller, with two smaller closure rollers to maintain engagement, makes contact with a lever having one end hinged to the stereoscope frame. The other end of the lever slides in a pivotted bracket on the main frame of the machine, conforming to the scheme outlined in Fig. 1. In this way the pencil carriage is moved in the Y-direction at the correct velocity ratio with respect to the stereoscope movement.

The pencil itself is carried on a hinged arm (with miniature ball bearings at the hinge point) which can be lifted by the finger from the paper, and held

there by spring action. When the pencil is lifted the point of contact with the paper is seen at the cross-wires of the viewing microscope. This permits rapid location of the plot from points and lines already registered.

Z Movement Mechanism

The foot disk is mounted on a vertical shaft having a telescoping portion and universal joint to permit variation in height and alignment—the main frame of the Stereograph being supported by three legs, adjustable in length. By the aid of bevel gears the foot disk drives a screw held in bearings just beneath the main frame, and perpendicular to the base direction. The nut of this screw, which always remains in mesh, is coupled to a trussed frame, also beneath the base, which moves the rail controlling the position of the bridge as compensation is made for variations in parallax on the photographs. A second portion of the trussed frame actuated from the Z movement screw is fitted with a pair of inclined rails forming a cam which moves the sleeve beneath the pencil carriage. This sleeve, as already explained, carries the rail guiding the auxiliary carriage on the pencil carriage, which forms the contact between the pencil carriage and the lever operated by the Y movement of the stereoscope.

Straight Edge

For ruling air bases on vertical photographs a steel straight-edge is mounted on two hinged arms. Ordinarily the straight-edge is out of the way against the stereoscope gantry supports, where it is held in place by spring plungers acting on the hinges. For use it is pulled down so as to lie over the photographs. In this position the working edge falls on the line joining the normal centres of rotation of the two photograph platens.

General

The Stereograph was designed with a view to avoiding precision adjustments in the shop. Great care was also taken to avoid unnecessary constraints and resistances to motion. Ball bearings were used wherever possible both at journals and as rollers at sliding contacts. Struts were employed at various places where shear forces were undesirable in the couplings. All the guides, pivots, etc., were mounted in such a way that opposing screws could be fitted for adjusting them into final location. No specially cut gears, or parts requiring the use of jigs or unique fixtures during fabrication, were used. The guide rails for the ball bearing rollers were made of cold rolled steel, with the working faces made flat and parallel on a surface grinder.

A program for adjustment was drawn up which permitted the Stereograph to be put into correct geometrical adjustment by observations made by or on the elements of the machine itself. The only external instrument required was an accurate set square to make the X and Y guides perpendicular to each other. Practically all the adjustment can be governed by observations through the stereoscope or the pencil carriage microscope.

Use

The Stereograph is now in use in the Air Surveys Office, Bureau of Geology and Topography, Department of Mines and Resources, Ottawa. It is mainly employed at present for plotting air bases for the control of strip plots, and allied work. The methods followed are more or less those described in Reference (2).

Acknowledgment

The Stereograph was built by Messrs. W. C. May and G. C. MacKiddie, who contributed a number of improvements to the author's original design for some of the elements and in this way, as well as by the conscientious workmanship put into the instrument, did a great deal to aid in its successful mechanical performance.

References

1. BURNS, E. L. M. and FIELD, R. H. Can. J. Research, A, 13 : 22-23. 1935.
2. BURNS, E. L. M. and FIELD, R. H. Can. J. Research, A, 15 : 85-99. 1937.
3. FIELD, R. H. Can. Surveyor, 5 : 2-11. 1937. (Reprinted in Phot. Eng. 3 : 42-49. 1937.)
4. FIELD, R. H. Eng. J. 22 : 391-399. 1939. (N.R.C. No. 848.)